Speed Habits Observed on a Rural Highway

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FIELD data combined for 2 years and postcard-survey information furnished a basis for analysis of the relation in this study of average speed to various driver and car characteristics. Higher speeds were associated with younger drivers, larger amounts of travel, and newer cars. But no combination of these factors could explain more than a small fraction of the total variance in speed.

The reappearance of drivers and individual speeds and average speeds for all observations were analyzed to establish features of the actual speed distributions preliminary to the statistical development of the analysis of speed variance between groups of drivers having different average speeds and among individual drivers. To compute the percentage of speeds above a specified value which are driven by any given percentage of the fastest drivers, a model was developed for a theoretical speed distribution based on assumptions of the driver's speed behavior and the empirical values of average speed and "within" and "between" speed variances. Procedures were developed for testing the theoretical deductions against the observed data. The agreement between theory and observation is excellent.

It was shown, for example, that about a third of all drivers have 85-percentile speed which exceed the 85-percentile value in the spot-speed distribution, and if a set of drivers are all observed as many as seven times, more than half of them can be expected to exceed the 85-percentile speed at least once.

Curves were developed showing the percentages of speeds above specified values which are driven by various percentages of the fastest and slowest drivers. The fastest 10 percent of the drivers provide a third of all the speeds faster than the 85-percentile. An average driver, i. e., a driver whose average speed is equal to the overall average, can be expected to exceed the 85-percentile speed about 11 percent of the time. The fastest 15 percent of the drivers contribute 46 percent of all the speeds over the 85 percentile speed.

● THE speed ranges of automobile drivers are important to all agencies interested in the design, operation, and control of the highway system. The spot speeds generally used may not be representative of the speed habits of all drivers. Today's average driver may be tomorrow's speeder.

The distribution of spot speeds at a particular location does not usually vary appreciably from one day to another, provided the observations are made at the same time each day. If the location is one where many of the drivers are repeaters (commuters, for example), a question arises concerning the habits of these drivers. Do some of them consistently exceed the average speed and others consistently fall below it? Or do they all average about the same speed, with different individuals driving the high speeds on different days? It is often said that only the highest 15 percent of the speeds are too fast, with the implication that the hazards of speeding could be greatly reduced by curbing 15 percent of the drivers. But no previous study has ever investigated whether 15 percent of the drivers drive too fast most of the time, or whether most drivers travel too fast 15 percent of the time.

The main purpose of the present study is to explore this question. The answer lies some-

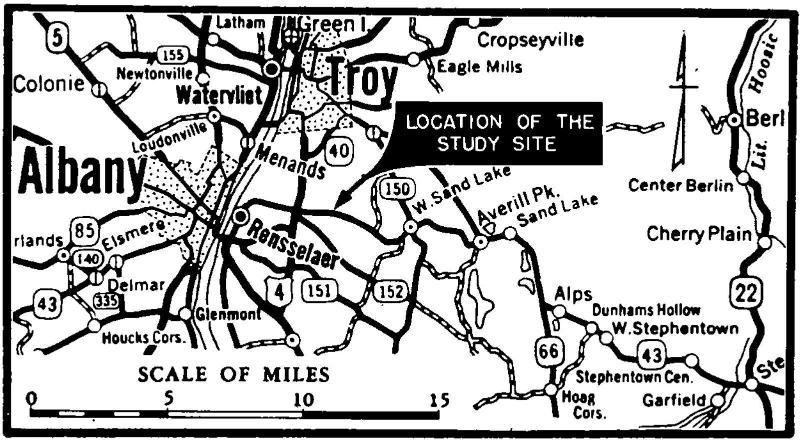

Figure 1.

where in between the two extremes described above. They point up the fundamental question which is to be investigated after it is defined in more precise terms.

A related question is this: If some drivers habitually drive faster than others, what else is different about them? We shall attempt to find out what characteristics of the drivers and their vehicles are associated with differences in average speed.

A previous investigation of this question was conducted more than 10 years ago by the Bureau of Public Roads in coöperation with the Institute of Human Relations, Yale University.[1] In comparison with the earlier study, the present one has the advantage of being based on more up-to-date driving behavior. In addition, the speed characterizing a particular driver is often an average of several observations in the present study, whereas the earlier investigation used only one observation on each driver. Thus the figures in the present report should more truly represent the driver's behavior.

A third question is also of interest: Are speed habits of the same drivers different at different types of locations? This possibility has been examined by observing each driver at two different locations within the study area.

[1] DeSilva, Harry R. "A Study of Motor-Vehicle Drivers and Speed in Connecticut," *Public Roads*, Vol. 21, No. 5 (July 1940), pp. 89–101.
DeSilva, Harry R. "Results from Speed Studies in Connecticut and South Carolina." *Proceedings of the Highway Research Board*. Vol. 20 (1940), pp. 702–706.

COLLECTION OF DATA

In choosing a location for the study, the following characteristics were desired: (1) the traffic volume should be sufficiently low so that most of the drivers are able to choose their speeds freely without regard to interference from other traffic; (2) there should be as many repeat drivers as possible; and (3) the study area should provide two locations of different geometric character, close enough together to permit the same drivers to be studied at both locations.

A location that met these conditions reasonably well was found about 5 miles east of Albany, New York (see Fig. 1). The road is a rural two-lane highway which carries mostly local traffic. It is used by a considerable number of commuters during the morning and afternoon peak hours.

Citybound traffic was studied during the peak 2 hours in the morning, while outbound traffic was studied during the afternoon peak period. The traffic volume was low enough to permit every vehicle to be clocked.

Data were collected on 14 different week days, eight in the summer of 1950 and six in the summer of 1951. Table 1 gives the days and hours of observation, the number of vehicles observed, and the average speed at each of the two locations during each observation period.

Figure 2 shows the plan and profile of the study area. The more-westerly location is near the center of a level tangent, and will

TABLE 1
NUMBER AND TYPE OF VEHICLES OBSERVED

Day of Week	Date	Type of Vehicle						Total Passenger & Suburban	Total of all Vehicles	Average Speed (mph.)			
		Pas-senger	Sub-urban[a]	Truck	Bus	Out of State Passenger	Other			All Vehicles		Pass. & Sub.	
										Sta. 3 curve	Sta. 4 tan.	Sta. 3 curve	Sta. 4 tan.
During the Morning From 7 to 9 O'Clock, 1950													
Th	7-27-50	152	6	11	1	2	4	158	176	42.0	43.6	42.1	44.1
F	7-28-50	240	10	25	1	3	4	250	283	39.8	43.2	39.9	43.7
Tu.	8-01-50	228	7	16	1	3	4	235	259	38.5	43.7	38.4	43.8
W.	8-02-50	148	8	12	1	1	—	156	170	35.4	41.8	35.3	42.5
Th.	8-03-50	216	7	18	1	3	2	223	247	38.1	44.4	38.1	44.6
F.	8-04-50	233	8	18	1	2	2	241	264	38.4	43.5	38.4	43.8
Totals..........		1217	46	100	6	14	16	1263	1399	38.7	43.4	38.9	43.9
During the Morning From 7 to 9 O'Clock, 1951													
Th.	8-23-51	183	3	17	1	5	1	186	210	40.2	46.0	40.6	46.5
F.	8-24-51	187	3	14	1	3	2	190	210	37.1	44.2	37.0	44.3
Tu.	8-28-51	195	6	14	1	2	2	201	220	38.8	45.9	38.9	46.0
W.	8-29-51	201	3	12	1	3	2	204	222	34.4	42.5	35.0	42.7
Totals..........		766	15	57	4	13	7	781	862	37.6	44.6	37.9	44.9
During the Afternoon From 4 to 6 O'Clock, 1950										Sta. 1 tan.	Sta. 2 curve	Sta. 1 tan.	Sta. 2 curve
W.	7-26-50	237	8	10	1	9	5	245	270	44.1	41.3	44.0	41.3
Th.	7-27-50	236	9	13	2	6	6	245	272	44.0	40.2	44.5	40.4
M.	7-31-50	244	7	18	1	5	5	251	280	45.6	37.9	46.2	37.8
Tu.	8-01-50	251	8	11	1	8	5	259	284	44.8	37.6	45.0	37.7
W.	8-02-50	127	3	7	0	4	0	130	141	43.6	38.2	44.2	38.4
Th.	8-03-50	239	9	21	1	8	4	248	282	44.0	36.4	44.3	36.4
F.	8-04-50	233	4	14	1	5	5	237	262	44.3	37.2	44.2	37.3
Totals..........		1567	48	94	7	45	30	1615	1791	44.4	38.4	44.7	38.6
During the Afternoon From 4 to 6 O'Clock, 1951													
W.	8-22-51	232	2	19	1	4	3	234	261	45.1	37.9	45.3	37.9
Th.	8-23-51	234	5	21	1	5	3	239	269	44.5	38.7	44.9	39.1
F.	8-24-51	207	6	15	1	10	4	213	243	43.9	38.9	44.0	38.9
M.	8-27-51	240	7	15	1	7	5	247	275	47.1	42.1	47.4	42.3
Tu.	8-28-51	243	7	20	1	5	3	250	279	43.0	37.8	43.1	37.6
Totals..........		1156	27	90	5	31	18	1183	1327	44.7	39.1	45.0	39.2

[a] The term *suburban* refers to station wagons and similar vehicles.

be referred to as the tangent location. The other location, about 600 feet to the east, is at the end of the tangent, where the pavement dips before going into a series of fairly sharp horizontal curves. The sight distance for eastbound traffic is quite limited. This location will be referred to as the curve location. When it is desired to distinguish between the eastbound and westbound (i.e., afternoon and morning) observations at the same location, they will be called *stations*. Station 1 is the tangent, eastbound; Station 2 the curve, eastbound; Station 3 the curve, westbound; and Station 4 the tangent, westbound. The photographs in Figure 3 show the driver's view of these locations.

The speeds of each vehicle were recorded by means of a speedmeter designed by the Bureau of Public Roads.[2] At each location a pair of rubber tubes were stretched across the road. Each vehicle crossing the tubes sent impulses to the speedmeter and timer, which

[2] The basic speed-measuring device is described by E. H. Holmes and S. E. Reymer in "New Techniques in Traffic Behavior Studies", *Public Roads*, Vol. 21, No. 2 (April 1940) pp. 30-37. However, the results were recorded by a specially wired adding machine instead of the 20-pen recorder.

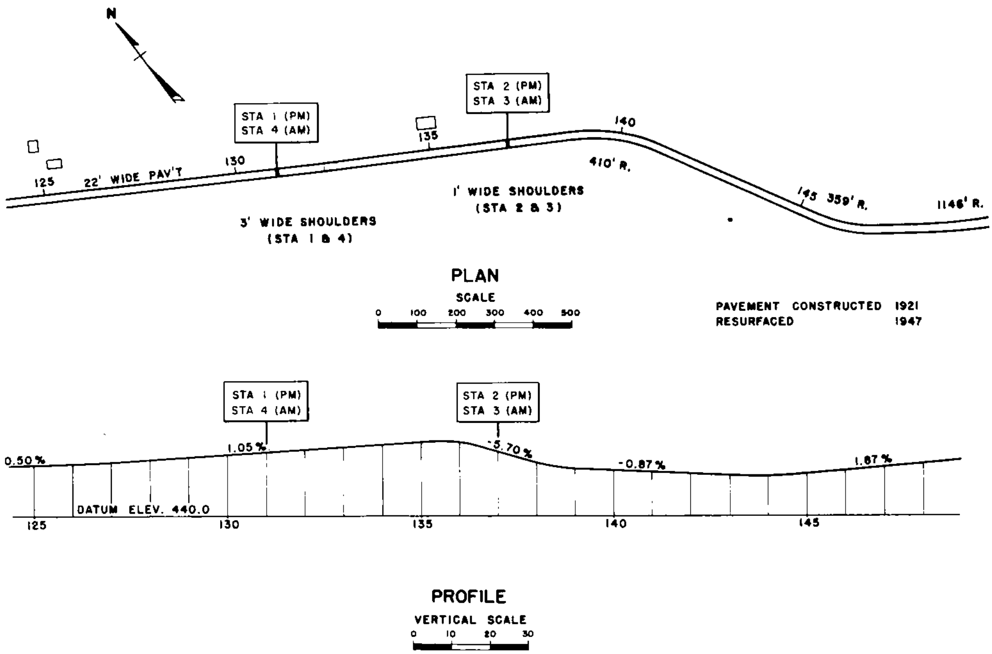

Figure 2. Plan and profile of the study area.

were in a parked truck. A specially wired adding machine printed a code representing the speed of the vehicle and also (for the 1951 samples only) the time of day to the nearest 0.0001 hour (0.36 second). The truck contained two speedmeter-adding-machine assemblies, one for each of the two locations.

Supplementing the mechanically recorded information, an observer noted the registration number for each passenger car or suburban carrying New York plates. The analysis was restricted to these cars. From the license number of each car observed in 1951, the name and address of the owner were obtained. Using this information the New York State Motor Vehicle Bureau furnished the year and make of the car and also its 1950 registration number. This permitted the correlation of 1950 and 1951 observations on each vehicle and their combination into a single group. Registration plate numbers were not recorded for trucks, busses, out-of-state vehicles, or vehicles having commercial plates (such as taxis, public cars, or those with dealer's plates).

Immediately after the 1951 observations were completed, a series of postcards was sent to each owner to find out who the driver was at the time his car was observed. A reproduction of one of these cards appears in Figure 4. In addition to the identity of the driver, the card also asked for the driver's age, occupation, and driving experience. Table 2 shows the extent to which the cards were returned. Each owner who responded returned every card sent him.

The names of owners and drivers were also used to examine the motor-vehicle-bureau reports of accidents in which they were involved. The analysis of these records has been treated as a separate research project and will be the subject of a companion report.

Altogether, 8,587 speed observations were obtained at the two locations. These involved 1,604 different drivers and were made in 22 observation periods. Of the drivers, 920 were seen only once. One had his speeds recorded during 21 of the 22 periods.

RELATION OF AVERAGE SPEED TO DRIVER AND CAR CHARACTERISTICS

General

It will be noted from Table 1 that the average speeds varied somewhat from one day to

VIEW APPROACHING STATION 1

VIEW APPROACHING VERTICAL CURVE

VIEW APPROACHING STATION 2

VIEWS WHEN OUT BOUND

VIEW AT STATION 3

VIEW APPROACHING STATION 4

VIEWS WHEN CITY BOUND

Figure 3.

VEHICLE REGISTRATION NO. 1951

WAS THE OWNER THE DRIVER OF THE YES ☐ IF NO GIVE NAME ....
CAR ON DATE NOTED IN LETTER NO ☐ DRIVERS ADDRESS ....

PLEASE FURNISH THE FOLLOWING INFORMATION ABOUT THE DRIVER (by checking proper places below)

AGE	NO. YEARS DRIVING	OCCUPATION	MILES DRIVEN PER YEAR
UNDER 18 ☐	UNDER 6 MOS. ☐	PROFESSIONAL ☐	UNDER 500 ☐
18 TO 20 ☐	6 MOS. TO 1 YR. ☐	BUSINESS ☐	500 TO 1000 ☐
21 TO 24 ☐	1 YR. TO 3 YRS. ☐	CLERKS - OFFICE ☐	1000 TO 5000 ☐
25 TO 29 ☐	3 YRS. TO 6 YRS. ☐	CHAUFFEUR ☐	5000 TO 10000 ☐
30 TO 39 ☐	6 YRS. AND OVER ☐	SALESMAN ☐	10000 TO 15000 ☐
40 TO 49 ☐		STUDENT ☐	OVER 15000 ☐
50 TO 59 ☐	AUG. 22 1951	SKILLED LABOR ☐	
60 TO 64 ☐		UNSKILLED LABOR ☐	
65 & OVER ☐	4 6 P.M.	OTHER ☐	

Figure 4. Questionnaire postal card mailed (one for each observation) to the car owner.

another. These differences are not large enough to require explanation. There was some effect when rain was actually falling. It was not considered worthwhile to exclude the rainy periods, because their effect on the overall average speed was negligible. They amounted to only 5 percent of the total observation time.

Age of Driver

Figure 5 shows how the average speed varies with the driver's age. There is a marked tendency for older drivers to have lower average speeds at all four stations. The trend is more consistent for the afternoon than for the morning observations.

TABLE 2
RETURNS OF POSTCARD QUESTIONNAIRE

		Drivers Observed in 1951			
		A.M. only	P.M. only	Both A.M. & P.M.	Total
Cards returned	Drivers	72	241	164	477
	cards	116	343	897	1356
Cards not returned	Drivers	66	207	53	326
	cards	96	241	261	598
Totals	Drivers	138	448	217	803
	cards	212	584	1158	1954
Percentage of returns	Drivers	52	54	76	59
	cards	55	59	78	69

Figure 6 shows the number of drivers in each age group. The cars driven by each age group of drivers are further subdivided according to the age of the car. The average car age for each driver age group is listed below.

Driver age, Years	*Average car age, Years*
Under 30	5.7
30–39	5.5
40–49	4.4
50–59	4.6
60 or over	5.2

The average car age is lowest for the drivers between 40 and 49 years old. It is highest for the youngest group of drivers.

Table 3 gives the average speeds for drivers of different ages subdivided by the age of the car. Figures are presented for each of the four stations. While it is difficult to visualize the patterns in such a large collection of figures, statistical analysis indicates a significant tendency for older drivers to have lower average speeds than younger drivers when driving cars of the same age. This is true for each of the four stations.

The driver's age appears again in Table 4, where the average speeds are given for a two-way classification by age of driver and miles

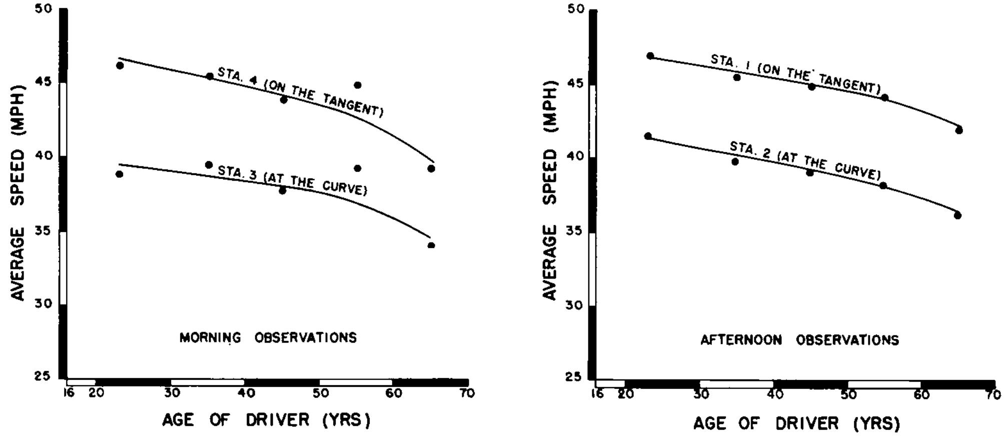

Figure 5. Average speed by age of driver.

driven per year. The older drivers tend to have lower average speeds than younger drivers with the same annual mileage.

Miles per Year

Table 4 also shows that drivers who travel less tend to drive more slowly. Figure 7 shows that people tend to do less driving as they become older.

Age of Car

Returning to Table 3, we find a tendency for drivers of a given age to drive more slowly when the cars are older. While this tendency is somewhat erratic, statistical analysis shows that it is significant at the afternoon stations but not at the morning stations. The relation between car age and average speed is illustrated in Figure 8.

None of these relations are consistent enough to permit accurate estimation of a driver's average speed. The average speeds of individual drivers show considerable variation above and below what would be expected on the basis of the driver's age, the age of his car, and the number of miles he drives in a year. The highest multiple correlation coefficient, that for Station 1, is only 0.341. This means that these three items of driver and car information explain only 12 percent (the square of 0.341) of the total variance in the average speeds, leaving the other 88 percent still unexplained.

Weight Class of Vehicles

The passenger cars were classified as light, medium, or heavy according to the brand name of the car. Table 5 groups the cars by age and weight class. There is no evidence that the average speed is affected by the weight of the car.

Driving Experience

Since 90 percent of the drivers were in one experience group (6 years or more of experience), there is no basis for determining the effect of driving experience on average speed.

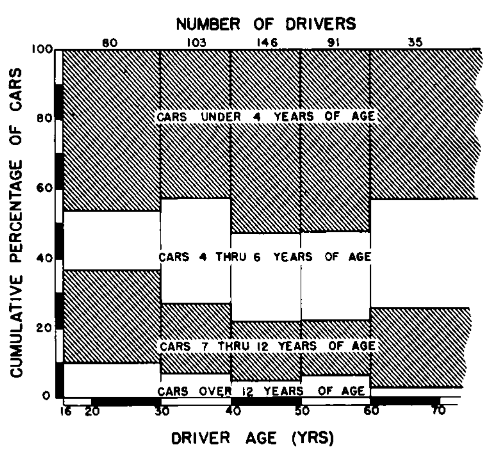

Figure 6. Car ages for each driver age group.

TABLE 3
RELATION BETWEEN THE AGE OF THE DRIVER, THE AGE OF THE CAR, AND THE AVERAGE SPEED DRIVEN

Age of Driver	Age of Car												Totals		
	0–3 Yrs.			4–6 Yrs.			7–12 Yrs.			13 Yrs. & Over					
	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)
Station 1 (During the afternoon on the tangent)															
Under 30..	28	81	47.2	12	26	49.5	13	39	45.6	10	18	44.9	63	164	46.9
30 to 39....	37	93	45.3	29	94	45.4	12	42	45.8	15	39	46.0	93	268	45.5
40 to 49....	66	214	45.6	34	77	45.7	11	26	43.0	14	34	40.5	125	351	44.9
50 to 59....	39	116	45.6	19	65	43.3	9	21	42.9	6	17	40.8	73	219	44.3
Over 59....	11	33	42.2	10	23	41.9	2	3	44.7	4	22	42.6	27	81	42.3
Totals...	181	537	45.6	104	285	45.1	47	131	44.7	49	130	43.1	381	1083	45.0
Station 2 (During the afternoon at the curve)															
Under 30..	28	76	40.8	12	26	43.1	13	39	42.7	10	18	38.3	63	159	41.4
30 to 39....	36	93	38.9	29	91	40.3	12	45	39.5	15	39	41.5	92	268	39.8
40 to 49....	66	210	39.9	34	77	39.2	11	28	36.0	14	35	36.1	125	350	39.1
50 to 59....	39	116	39.5	20	63	37.8	9	20	37.4	6	17	35.1	74	216	38.4
Over 59....	11	33	37.4	10	23	34.5	3	4	33.8	4	23	36.8	28	83	36.3
Totals...	180	528	39.6	105	280	39.2	48	136	39.2	49	132	38.0	382	1076	39.2
Station 3 (During the morning at the curve)															
Under 30..	19	67	39.9	8	24	37.2	9	34	37.4	4	7	41.6	40	132	38.9
30 to 39....	26	83	39.5	19	77	39.2	9	30	38.6	7	27	41.1	61	217	39.5
40 to 49....	47	159	37.9	20	54	38.9	8	20	40.1	9	23	33.3	84	256	37.8
50 to 59....	26	95	40.6	8	40	40.1	7	18	38.8	6	20	32.7	47	173	39.3
Over 59....	8	29	32.9	3	6	33.5	1	1	26.0	5	24	36.3	17	60	34.2
Totals...	126	433	38.8	58	201	38.9	34	103	38.4	31	101	36.5	249	838	38.5
Station 4 (During the morning on the tangent)															
Under 30..	18	70	47.1	8	26	43.7	9	34	44.8	4	7	52.6	39	137	46.2
30 to 39....	25	78	46.4	19	77	44.7	9	29	44.3	8	28	46.2	61	212	45.5
40 to 49....	46	158	43.9	19	54	45.5	8	21	46.6	8	22	38.0	81	255	44.0
50 to 59....	26	95	45.7	8	37	44.9	6	15	47.7	6	23	40.0	46	170	45.0
Over 59...	8	29	37.5	3	6	39.8	—	—	—	5	22	41.8	16	57	39.4
Totals...	123	430	44.8	57	200	44.7	32	99	45.5	31	102	42.5	243	831	44.6

Occupation of Driver

Table 6 shows the average speeds for the various occupation groups. Average speeds do not appear to differ much between occupations except for the chauffeurs, who apparently tend to drive faster than the others. However, the sample of chauffeurs is too small to be of much value.

Owners versus Nonowners

It may be asked whether the drivers for whom postcards were returned were typical of all the drivers in the study. It is also of interest to find out whether the individuals who were driving their own cars behaved any differently from those who were not the owners of the cars they were driving.

Table 7 gives the average and 85-percentile speeds at each station for owners, nonowners, and those who did not return their postal cards. There are no significant differences among the three groups. The fact that this is true for the 85-percentile as well as the average speeds means that the speed ranges are also about the same for all three groups of drivers.

Of the 67 cars reported to have been driven by nonowners, all but 14 were driven by the same individual throughout the survey. In all the speed analyses the unit of study is the driver, not the car.

Summary

The principal factors affecting the average speeds of different drivers are the driver's

TABLE 4

RELATION BETWEEN THE AGE OF THE DRIVER, THE MILES DRIVEN PER YEAR AND THE AVERAGE SPEED DRIVEN

Age of Driver	Miles Driven per Year												Totals		
	Under 5000			5000 to 10000			10000 to 15000			Over 15000					
	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)
Station 1 (During the afternoon on the tangent)															
Under 30	15	27	46.8	17	45	44.2	13	48	48.0	25	58	48.4	70	178	47.0
30 to 39	13	34	45.8	30	102	45.4	32	93	45.2	21	42	46.2	96	271	45.5
40 to 49	30	75	43.1	37	107	44.8	36	118	45.4	29	58	46.1	132	358	44.8
50 to 59	25	59	43.4	27	80	43.0	17	62	46.3	12	37	44.7	81	238	44.2
Over 59	12	29	42.5	7	22	41.4	6	19	42.9	4	13	43.6	29	83	42.5
Totals	95	224	44.0	118	356	44.3	104	340	45.7	91	208	46.3	408	1128	45.0
Station 2 (During the afternoon at the curve)															
Under 30	15	26	38.4	17	44	39.4	13	46	40.9	25	56	43.8	70	172	41.1
30 to 39	13	34	37.4	30	102	40.1	32	93	39.5	20	42	41.5	95	271	39.8
40 to 49	30	77	37.9	37	102	38.0	36	120	39.5	29	58	41.3	132	357	39.0
50 to 59	25	62	38.2	29	76	36.9	17	62	39.5	12	35	40.3	83	235	38.4
Over 59	13	30	36.3	8	24	35.5	6	20	38.0	4	12	33.5	31	86	36.1
Totals	96	229	37.8	121	348	38.4	104	341	39.6	90	203	41.4	411	1121	39.2
Station 3 (During the morning at the curve)															
Under 30	10	21	36.4	11	37	37.2	7	32	38.9	15	47	40.8	43	137	38.7
30 to 39	8	23	37.0	23	73	39.1	22	95	39.8	8	26	41.5	61	217	39.5
40 to 49	18	47	35.4	23	74	37.7	25	98	38.3	20	40	39.6	86	259	37.8
50 to 59	12	46	37.6	15	57	38.6	13	52	41.1	9	27	41.3	49	182	39.5
Over 59	7	27	32.0	4	16	33.6	3	14	37.9	3	3	39.7	17	60	34.2
Totals	55	164	35.8	76	257	38.0	70	291	39.3	55	143	40.7	257	855	38.5
Station 4 (During the morning on the tangent)															
Under 30	10	21	45.8	10	39	44.6	7	36	45.7	15	46	48.4	42	142	46.3
30 to 39	8	22	45.9	23	74	44.6	22	93	45.3	8	23	48.5	61	212	45.5
40 to 49	16	44	41.1	22	74	44.1	24	100	44.5	20	39	45.4	82	257	43.9
50 to 59	12	43	44.5	14	55	44.4	13	54	46.1	9	27	44.7	48	179	45.0
Over 59	6	24	36.9	5	16	41.5	3	15	40.7	2	2	41.0	16	57	39.3
Totals	52	154	42.7	74	258	44.2	69	298	45.0	54	137	46.7	249	847	44.6

age, the age of the car, and the annual amount of driving. The faster speeds are driven by younger drivers, by people in newer cars, and by people who drive higher annual mileages. However, none of these factors go far toward explaining an individual's average speed; the variation of average speeds within most of these groups is almost as great as the variation for all drivers.

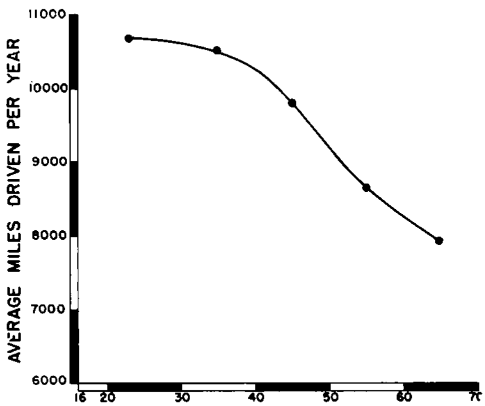

Figure 7. Annual mileage versus age of driver.

SPEED DISTRIBUTIONS

Reappearance of Drivers

It has already been pointed out that the drivers were not all observed the same number of times. Some were observed only once, some twice, some three times, and so on. It will help in understanding the speed distributions

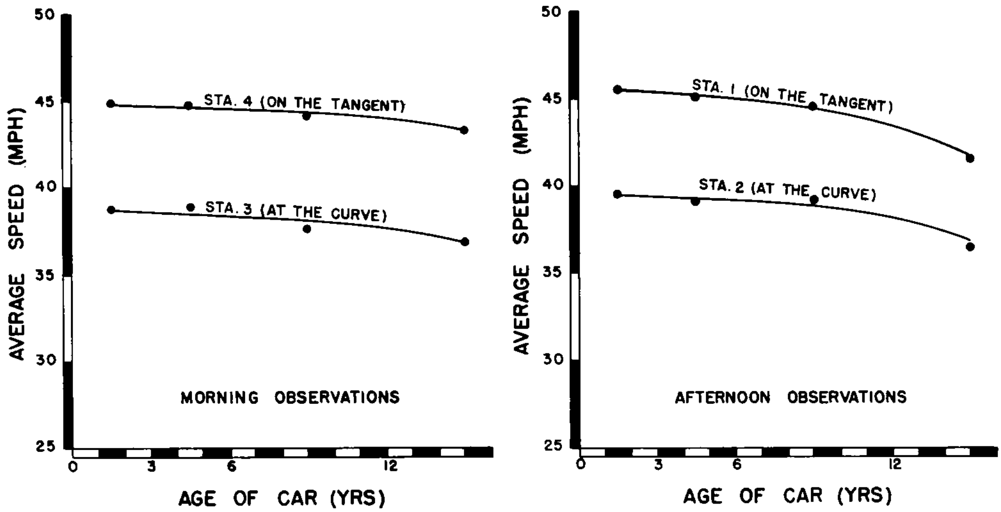

Figure 8. Average speed by age of car.

TABLE 5

RELATION BETWEEN THE WEIGHT CLASS OF CAR, THE AGE OF CAR AND THE AVERAGE SPEED DRIVEN

Weight Class of Car	Age of Car												Totals		
	0–3 Yrs.			4–6 Yrs.			7–12 Yrs.			13 Yrs. & Over					
	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)
Station 1 (During the afternoon on the tangent)															
Light	68	212	44.7	41	125	44.4	23	55	44.3	25	67	44.9	157	459	44.6
Medium	96	285	46.4	51	137	45.6	19	54	44.3	18	42	41.5	184	518	45.6
Heavy	9	20	44.7	11	22	45.9	5	22	46.6	6	21	40.8	31	85	44.5
Suburban	9	25	43.9	1	1	52.0	—	—	—	—	—	—	10	26	44.2
Totals	182	542	45.6	104	285	45.1	47	131	44.7	49	130	43.1	382	1088	45.1
Station 2 (During the afternoon at the curve)															
Light	68	206	39.0	41	117	38.8	24	58	38.9	25	67	39.4	158	448	39.0
Medium	97	284	40.1	52	140	39.5	19	54	40.2	18	42	35.9	186	520	39.6
Heavy	8	18	37.2	11	22	38.5	5	24	37.6	6	23	37.5	30	87	37.7
Suburban	9	26	39.0	1	1	46.0	—	—	—	—	—	—	10	27	39.3
Totals	182	534	39.5	105	280	39.2	48	136	39.0	49	132	38.0	384	1082	39.3
Station 3 (During the morning at the curve)															
Light	46	149	37.5	25	89	40.0	17	53	38.3	16	56	38.6	104	347	38.4
Medium	67	244	39.9	24	91	38.2	12	34	36.4	12	34	33.0	115	403	38.6
Heavy	8	25	37.0	8	20	36.5	5	16	43.0	3	11	36.6	24	72	38.1
Suburban	6	16	37.3	1	1	39.0	—	—	—	—	—	—	7	17	37.4
Totals	127	434	38.8	58	201	38.8	34	103	38.4	31	101	36.5	250	839	38.5
Station 4 (During the morning on the tangent)															
Light	44	148	44.3	24	92	45.3	18	52	45.1	17	55	43.5	103	347	44.5
Medium	65	243	45.4	23	87	44.5	11	33	44.6	11	36	40.4	110	399	44.7
Heavy	9	24	42.8	8	20	43.0	4	14	49.0	3	11	44.0	24	69	44.3
Suburban	6	16	45.0	1	1	46.0	—	—	—	—	—	—	7	17	45.1
Totals	124	431	44.9	56	200	44.7	33	99	45.5	31	102	42.5	244	832	44.6

TABLE 6
RELATION BETWEEN THE OCCUPATION OF THE DRIVER AND THE AVERAGE SPEED DRIVEN

Occupation	Station 1			Station 2			Station 3			Station 4		
	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)	Drivers	Observations	Ave. Speed (MPH)
Professional	80	246	45.5	82	238	38.9	61	226	38.3	61	220	44.4
Business	102	216	45.4	103	213	40.0	62	185	39.7	56	173	45.2
Off. Clerk	37	144	45.0	38	154	39.2	26	115	37.7	26	114	44.2
Chauffeur	8	29	47.9	7	19	43.4	4	9	43.1	4	8	50.1
Salesman	20	50	46.2	20	49	40.8	19	49	39.0	19	49	44.6
Student	11	22	45.4	11	22	39.4	8	9	37.1	8	9	45.3
Skilled Labor	96	307	44.7	96	316	39.2	62	210	38.3	61	220	44.7
Unskilled Labor	15	48	43.1	15	48	35.9	6	28	35.2	6	30	43.1
Other	49	83	43.4	51	81	36.9	16	29	38.0	13	23	46.9

if we first examine the pattern of these repetitions.

Table 8 shows how many of the drivers observed each day were being seen for the first time that year traveling in that direction, how many for the second time, and so on. For example, of the 259 drivers observed during the fourth afternoon in 1950, 41 percent had not been seen in previous afternoons, 26 percent were being seen for the second time in the afternoon, 19 percent for the third time, and 14 percent for the fourth time. Even as late as the seventh afternoon, only two thirds of the drivers were repeaters who had gone by in one or more previous afternoons.

Figure 9 illustrates one of the principal conclusions from this table. The average frequency of appearance is plotted against the number of days the study operated. Consider, for example, the drivers observed in the afternoon in 1950. At the end of the fourth day, the drivers observed in the 4 days had been seen an average of 1.5 times each. After 7 days, the average had increased to 1.8 times per driver. However, this applies to all the drivers observed during the 7 days, including some who did not appear during the first 4 or even the first 6 days. It has been calculated from Table 8 that the drivers who were observed during the first 4 days had been seen an average of 2.1 times in the entire 7 days.

It was not considered desirable to combine the afternoons (or mornings) of the two years into a single series, because of the sharp break in continuity in going from the first year to the second. By the last afternoon of 1950 only 34 percent of the drivers were new to the study, whereas 66 per cent of the drivers observed in the first afternoon of 1951 had not been seen in any 1950 afternoon. The corresponding percentages for the mornings are 14 and 57, respectively.

The 1950 afternoons had the lowest repetition rate. There was somewhat more repetition in 1951 than in 1950, and considerably more in the mornings than in the afternoons. The latter fact suggests that the commuters may be more inclined to vary the time (or perhaps the route) of travel when they are returning home at the end of the day than when they are going into the city in the morning.

Figure 10 shows the proportions of drivers observed once, twice, etc., in the entire study (both years combined). The figure also shows

TABLE 7
OBSERVED RELATION OF CAR OWNERSHIP TO SPEED

Identity	Drivers	Observations	Speed in M.P.H.	
			Average	85 Percentile
Station 1 (During the afternoon on the tangent)				
Owner	335	981	45.1	50.3
Non-owner	67	143	44.8	51.6
Unknown	277	500	44.4	50.0
Station 2 (During the afternoon at the curve)				
Owner	338	976	39.3	45.4
Non-owner	66	140	38.1	45.1
Unknown	270	494	38.8	45.9
Station 3 (During the morning at the curve)				
Owner	220	764	38.5	43.3
Non-owner	37	86	38.7	42.5
Unknown	133	318	37.9	44.3
Station 4 (During the morning on the tangent)				
Owner	217	764	44.6	49.4
Non-owner	34	80	44.9	49.2
Unknown	131	310	44.0	49.5

TABLE 8
REAPPEARANCE OF DRIVERS

	1950 Morning											
	July 27		July 28		Aug. 1		Aug. 2		Aug. 3		Aug. 4	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
First time observed	157	99	156	62	95	40	39	25	37	17	34	14
Second time observed	1	1	94	38	78	33	38	24	45	20	32	13
Third time observed					62	27	45	29	53	24	41	17
Fourth time observed							34	22	56	25	51	21
Fifth time observed									32	14	51	21
Sixth time observed											32	14
Totals	158	100	250	100	235	100	156	100	223	100	241	100

	1951 Morning							
	Aug. 23		Aug. 24		Aug. 28		Aug. 29	
	No.	%	No.	%	No.	%	No.	%
First time observed	186	100	71	37	64	32	47	23
Second time observed			119	63	41	20	38	19
Third time observed					96	48	38	19
Fourth time observed							81	39
Totals	186	100	190	100	201	100	204	100

	1950 Evening													
	July 26		July 27		July 31		Aug. 1		Aug. 2		Aug. 3		Aug. 4	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
First time observed	245	100	169	69	139	55	106	41	41	32	90	36	83	34
Second time observed			76	31	65	26	67	26	26	20	26	10	21	9
Third time observed					47	19	49	19	29	22	46	19	28	12
Fourth time observed							37	14	21	16	39	16	37	16
Fifth time observed									13	10	34	14	34	14
Sixth time observed											13	5	25	11
Seventh time observed													9	4
Totals	245	100	245	100	251	100	259	100	130	100	248	100	237	100

	1951 Evening									
	Aug. 22		Aug. 23		Aug. 24		Aug. 27		Aug. 28	
	No.	%	No.	%	No.	%	No.	%	No.	%
First time observed	234	100	137	57	98	46	105	42	92	36
Second time observed			102	43	52	24	45	18	43	17
Third time observed					63	30	49	20	32	13
Fourth time observed							48	20	44	18
Fifth time observed									39	16
Totals	234	100	239	100	213	100	247	100	250	100

the proportions of the total number of observations contributed by each of these groups of drivers. There are separate charts for the mornings, the afternoons, and the mornings and afternoons combined.

Individual Speeds

Figure 11 shows the distribution of all the individual speed observations at each of the four stations. At all four stations the distributions are approximately normal. The differences between morning and afternoon are minor, while the differences between tangent and curve are considerable. The average speed at the two tangent stations (Stations 1 and 4 combined) was 44.6 mph., as contrasted with 38.7 mph. at the curve stations.

Average Speeds

When the average speed of each driver is used instead of the individual speed observations, different distributions are obtained depending on the number of times each driver was observed. These distributions all have about the same average speed, but the range becomes narrower as the number of observations per driver increases. This is because averages of a large number of observations have less dispersion than averages based on a smaller number.

The solid and dashed curves in Figure 12 give the cumulative distributions of the average speeds of drivers observed once, two to four times, and five or more times at the tangent location (both years, morning and afternoon combined). The curves become progressively steeper in their central portions as the number of observations increases, and the very-high and very-low speeds become progressively less frequent. The theoretical distribution is shown by the dotted curve. This is the distribution that would be expected if every driver in the study had been observed a sufficient number of times to determine his average speed without sampling error and the exact distribution of his individual speeds about this average. The method of developing this curve is described in a later section of the report.

It would have been desirable to have a larger number of observations on every driver. With enough observations we could have determined with negligible sampling error the average speed of each driver at the study locations. We could also have found the exact distribution of his individual speeds about

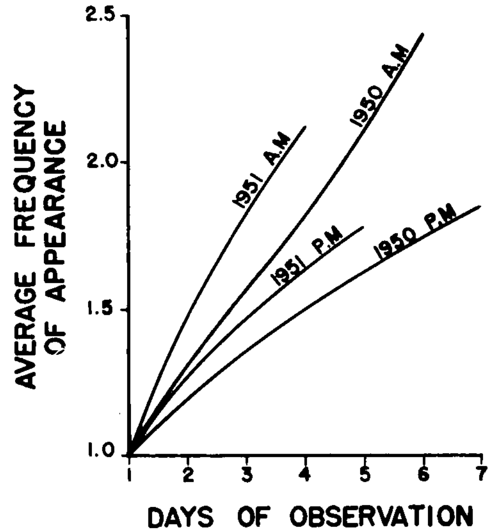

Figure 9. Average frequency of driver appearance.

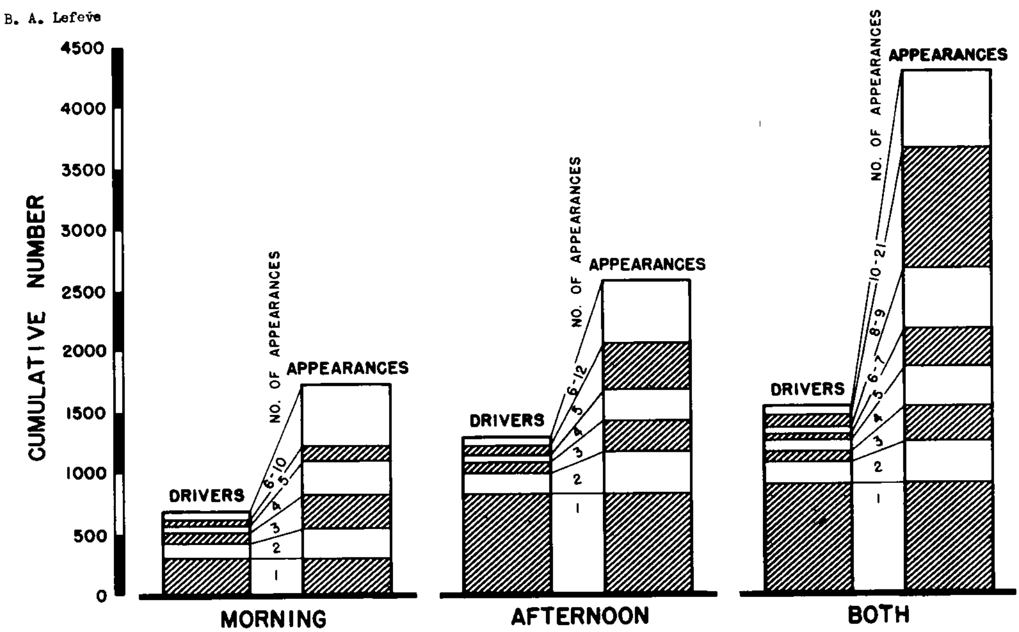

Figure 10(a). Numbers of appearances of drivers who appeared various number of times.

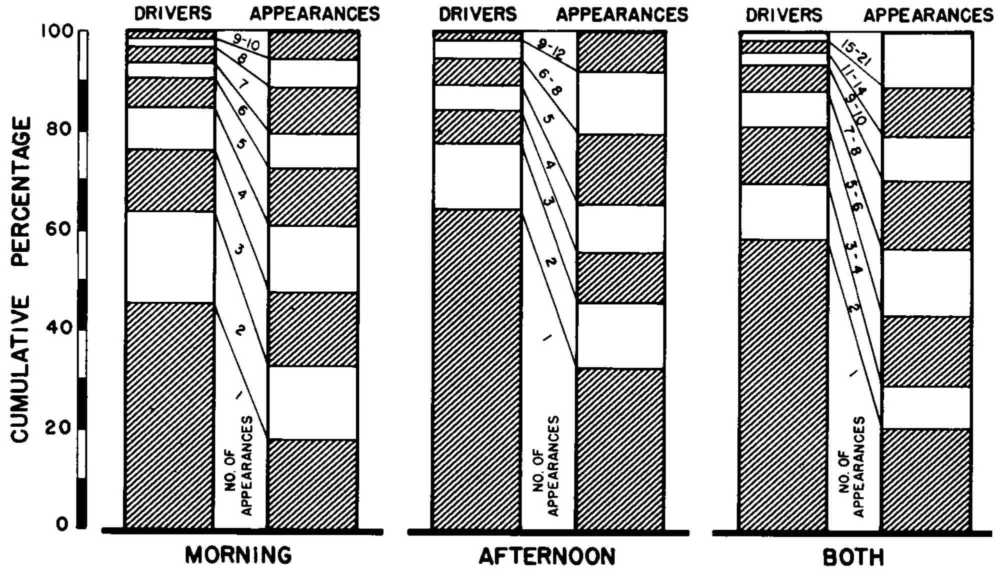

Figure 10(b). Proportions of appearances of drivers who appeared various number of times.

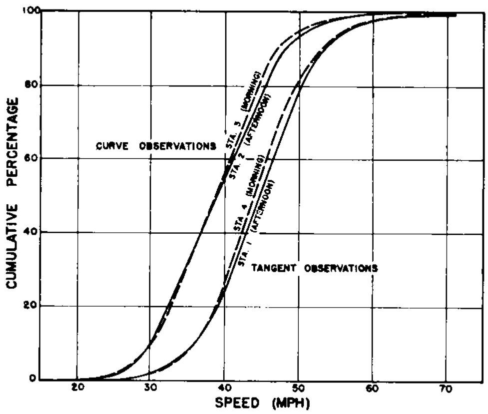

Figure 11. Distribution of speed observations at each station.

this average. The drivers could then have been rated both by their average speeds and by their variability.

Unfortunately, the number of observations per driver required is far beyond what was available in the present study. It would take 87 observations on each driver to estimate his variance[3] to within ±20 percent with 80 percent confidence. Even this low degree of precision is outside our grasp, since no driver was observed more than 21 times at either of the two locations.

Variance Analysis

Reliable estimates may be made of the average variability of speeds for the whole group of drivers even though the value for any particular driver may have a considerable sampling error. This is done by applying the statistical technique known as the analysis of variance.

The dispersion of individual speeds has been separated into two parts by this analysis. The first part represents the fact that some drivers have higher average speeds than others. Since this part reflects differences be-

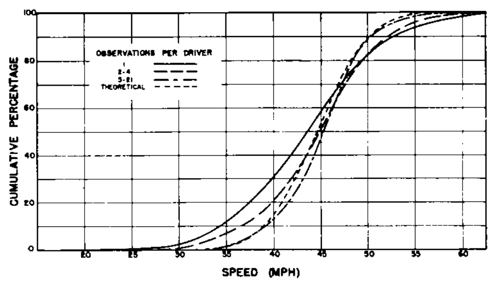

Figure 12. Distribution of average speeds at the tangent location.

[3] The square of the standard deviation of his speeds at the same place on different days. This quantity approaches a stable value as more and more observations are obtained.

tween drivers, it will be called the "between" variance. The second part represents the fact that most drivers travel faster on some days than on others. Since this variation is within the range of performance of an individual driver, it will be called the "within" variance.

The between and within variances were calculated separately for each of the four stations. The procedure used all the data on every driver and took into account that some drivers were observed more times than others. Table 9 lists these variances and the average speed for each of the four stations. Note that the average speed is appreciably higher at the tangent stations than at the curve stations, but the variances do not have any such consistent differences. For this reason, it was decided better estimates of the variances could be computed by combining all four stations.

What do these figures mean? A variance is the square of the standard deviation of a distribution. Thus the within variance of 32.2 (whose square root is 5.67) means that the typical driver, if observed a large number of times at the same location, would have speeds distributed about his particular average speed with a standard deviation of 5.67 mph. The data suggest that this value would apply equally to the tangent or the curve. The between variance of 18.8 (square root 4.33) means that, if each driver were observed enough times at one location to get his "true" average speed without sampling error, then the average speeds of different drivers at that location would be distributed about the average for all drivers with a standard deviation of 4.33 mph.

These results are important. The fact that the within variance is larger than the between variance means that the average variation in speed performance of individual drivers is greater than the variation among different drivers. We can now examine the questions posed at the beginning of the report as to which drivers are driving the fastest 15 percent of the speeds, and what speeds are driven by the fastest 15 percent of the drivers. But to do this requires the development of a little theory.

Theoretical Distributions

The theoretical model involves the three assumptions given below, plus the empirical

TABLE 9
AVERAGE SPEED AND VARIANCES AT EACH LOCATION

Station	Average speed	Between variance	Within variance
	(*mph*)	(*mph*)^2	(*mph*)^2
1 (tangent, afternoon)......	44.8	16.2	36.4
2 (curve, afternoon)........	38.8	18.9	34.3
3 (curve, morning)..........	38.5	17.2	29.1
4 (tangent, morning)........	44.3	20.2	27.6
All stations combined......		18.8	32.2

values of average speed and within and between variances. Deductions from the theory have been tested against the actual data wherever this has been possible, and in all such cases the agreement has been excellent.

The following statements are assumed to apply to each of the two locations:[4]

1. All drivers have equal variability. For each driver, the speeds on different days form a normal distribution about his particular average speed.

2. The average speeds of individual drivers form a normal distribution about the average for all drivers.

3. There is no relation between a driver's average speed and the frequency with which he passes the study location.

The first and second assumptions, combined, are tested two ways. First, the theoretical distribution of individual speed observations for all drivers at the tangent location (morning and afternoon combined) is compared with the actual distribution in Figure 13. The two curves agree closely. Also shown in Figure 13 are the theoretical distribution of average speeds and the distribution of the 85-percentile speeds of different drivers. It is interesting to note that more than a third of the drivers have 85-percentile speeds exceeding the 85-percentile point on the individual speed curves. This can be seen from the fact that the latter (which would normally be called simply the 85-percentile speed) is 51.5 or 52.0 mph., depending on whether we use the actual or the theoretical

[4] For the benefit of the mathematically inclined, these assumptions can be summarized in the single statement that the joint distribution of average speeds x and individual speeds y is given by

$$f(x, y)dxdy =$$

$$\frac{1}{2\pi\sigma_w\sigma_b} \exp\left[-\frac{1}{2}\left(\frac{y-x}{\sigma_w}\right)^2 - \frac{1}{2}\left(\frac{x-m}{\sigma_b}\right)^2\right] dxdy$$

where σ_w^2 is the within variance, σ_b^2 is the between variance, and m is the over-all average speed.

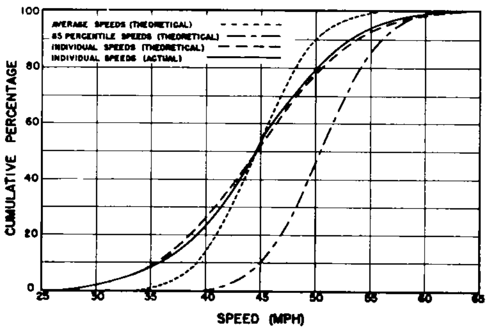

Figure 13. Distributions of Speeds at the tangent location.

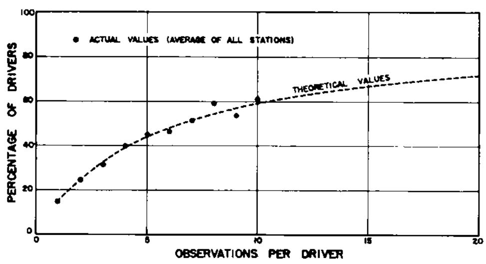

Figure 14. Percentage of drivers whose maximum speed exceeds the 85-percentile speed.

curve. The percentage of the drivers having 85-percentile speeds below this value is 59–64. Therefore the proportion of the drivers having 85-percentile speeds above this value is 36–41 percent, i.e., more than a third.

A second test was made by computing at each location for each reoccurrence group the 85-percentile speed and the percentage of drivers whose maximum speed exceeded this value. These percentages are compared with the theoretical values in Figure 14. Again the agreement between theory and observation is good.[5]

The second assumption is further verified in Figure 12, where the cumulative distributions of average speeds for several groups of drivers are compared with the theoretical distribution. The empirical curves become more and more like the theoretical curve as the number of observations per driver increases. Comparing the theoretical curve with the actual distribution for drivers observed five times or more, the latter has a slightly higher average and is a little skewed toward the low speeds. The theoretical model is not a perfect fit to the actual distributions, but it is close enough so that the deductions which follow are at least approximately correct.

The third assumption is verified from the distributions of speeds for drivers observed different numbers of times. Statistical analysis shows that it is safe to assume that drivers observed different numbers of times have similar average speeds.

From this theory it is possible to compute the percentage of speeds above a specified value which are driven by any given percentage of the fastest drivers. For instance, consider speeds over 60 mph. at the tangent location. It is obvious that the drivers who average 50 mph. will exceed 60 mph. more often than those whose average is 45 mph. On the other hand, there are more of the latter kind. Without using some such theory as has been developed here, there would be no way to determine what proportion of the speeds over 60 mph. is driven by the 10 percent of the drivers having the highest average speeds.

Figure 15 provides information of this kind. It uses the average speed of 44.6 mph. that was found at the tangent stations. It shows, for example, that the fastest 10 percent of the drivers contribute 62 percent of the speeds over 60 mph., 44 percent of the speeds over 55 mph., and 28 percent of the

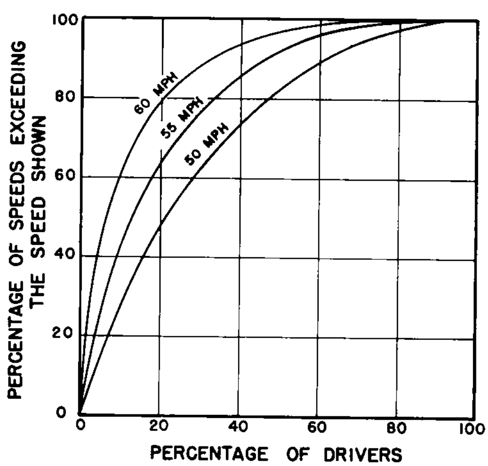

Figure 15. Percentage of speeds contributed by various groups of the fastest drivers at the tangent location.

[5] As a numerical example, the theory says that a driver observed five times should have a 44-percent chance of exceeding the 85-percentile speed at least once. Actually, at the four stations the percentages of drivers observed five times whose maximum speeds exceeded the 85-percentile speeds at their respective location were 45.3, 44.3, 46.3, and 43.5.

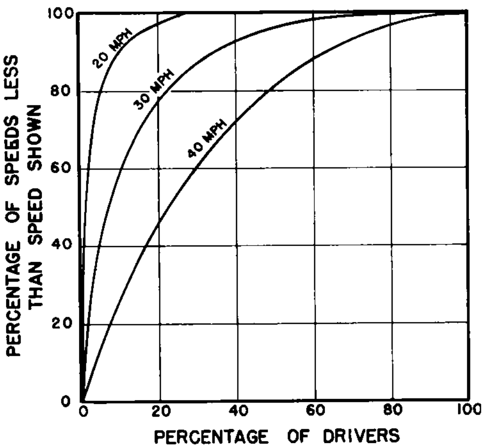

Figure 16. Percentage of speeds contributed by various groups of the slowest drivers at the tangent location.

speeds over 50 mph. Corresponding percentages of speeds for other percentages of drivers can easily be read from the graph.

The graph is not really restricted to roads having an average speed of 44.6 mph. For any location having the within and between variances given in the last row of Table 9, the 60-mph. curve will apply to the speed 15.4 mph. above the average, the 55-mph. curve will apply to the speed 10.4 mph. above the average, and the 50-mph. curve will apply to the speed 5.4 mph. above the average.

Figure 16 gives similar information about the slowest drivers and the speeds below

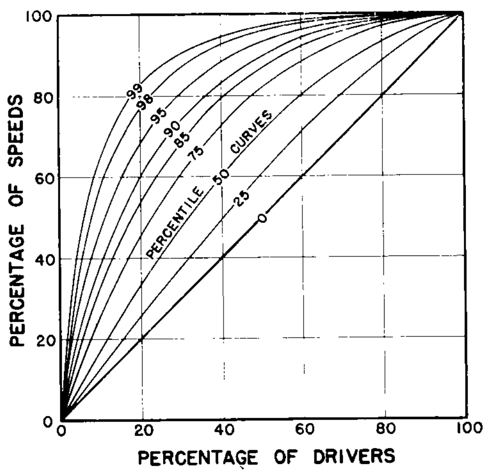

Figure 17. Percentage of speeds contributed by various groups of drivers at the tangent location.

TABLE 10
SPEEDS DRIVEN BY VARIOUS GROUPS OF DRIVERS

Groups of drivers arranged according to their average speeds	Percentage of speeds: Above the 85-percentile	Percentage of speeds: Below the 15-percentile
Fastest 10 percent	34	1
Second fastest 10 percent	21	1
Third fastest 10 percent	14	2
Fourth fastest 10 percent	11	4
Fifth fastest 10 percent	7	5
Sixth fastest 10 percent	5	7
Seventh fastest 10 percent	4	11
Eighth fastest 10 percent	2	14
Ninth fastest 10 percent	1	21
Slowest 10 percent	1	34
Total	100	100

various values. It shows, for example, that at the tangent station the slowest 10 percent of the drivers contribute 90 percent of the speeds under 20 mph., which means that the other 90 percent of the drivers contribute only 10 percent of these very slow speeds. (The counterpart in Figure 15 of this 20-mph. curve would be a curve for 69.2 mph., which is the same distance above the average speed of 44.6 mph. as 20 mph. is below it.) Similarly, the slowest 10 percent of the drivers drive 59 percent of the speed under 30 mph. and 27 percent of the speeds under 40 mph. The 30- and 40-mph. curves in Figure 16 correspond approximately to the 60- and 50-mph. curves in Figure 15.

Figure 17 generalizes the two preceding figures by giving the speeds as percentiles of the spot speed distribution instead of stating them in miles per hour. This graph is valid for any average speed and any within and between variances having the same ratio as those of Table 9. The graph applies to any of the four stations taken separately, to the two tangent stations combined, and to the two curve stations combined.

The meaning of a point (x, y) on the z-percentile curve is two-fold: (1) the fastest x percent of the drivers contribute y percent of the speeds above the z-percentile speed; (2) the slowest x percent of the drivers contribute y percent of the speeds below the $(100 - z)$ percentile speed. This graph provides the answers to the questions posed near the beginning of the report concerning the fastest 15 percent of the speeds and the fastest 15 percent of the drivers.

Information about who drives the fastest

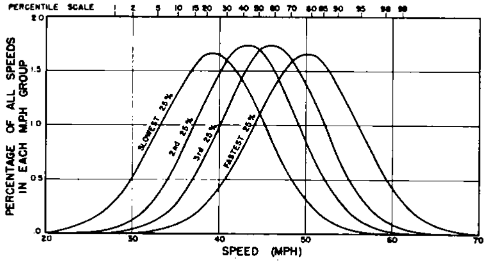

Figure 18. Distribution of individual speed observations for several groups of drivers at the tangent location.

15 percent of the speeds comes from the 85-percentile curve in Figure 17. The fastest 10 percent of the drivers drive 34 percent of these speeds, while the next-fastest 10 percent drive 21 percent of them; the slowest 30 percent of the drivers drive only 4 percent of the speeds above the 85-percentile. Table 10 gives the percentage of these speeds driven by each tenth of the drivers. The last column of the table illustrates the application of the same curve to speeds below the 15-percentile point.

Information about the fastest 15 percent of the drivers would come from a vertical line drawn for an abscissa of 15 percent. It would show that these drivers contribute 61 percent of the speeds over the 95-percentile, 46 percent of the speeds over the 85-percentile, 37 percent of the speeds over the 75-percentile, and 26 percent of the speeds over the median. From these percentages one can compute that the fastest 15 percent of the drivers drive 13 percent of the speeds under the 95-percentile, 10 percent of the speeds under the 85-percentile, 8 percent of the speeds under the 75-percentile, and 4 percent of the speeds under the median.[6]

The 0-percentile curve is the 45-deg. line along which the percentage of speeds and the percentage of drivers are equal. Since "speeds above the 0-percentile" are all the speeds, this simply means that the fastest x percent of the drivers drive x percent of all the speeds. Using the other interpretation of the graph, it also means that the slowest x percent of the drivers drive x percent of all the speeds.

[6] The formula is based on the fact that if the fastest x percent of the drivers drive y percent of the speeds over the z-percentile and u percent of the speeds under the z-percentile, then $y\ (100\text{-}z) + uz$ must add up to $100x$, since x percent of the drivers drive x percent of all the speeds.

Another application of the theory is in subdividing the total speed distribution into parts contributed by different groups of drivers. This kind of information could tell us, for example, what the spot-speed distribution would be like if the fastest 15 percent of the drivers were ruled off the highway. Or it could show us the distribution of all the spot speeds driven by these fast drivers.

Actually, neither of these distributions was worked out. However, the drivers have been grouped in two different ways. Figure 18 gives the result of dividing the drivers into four equal groups: the 25 percent having the slowest average speeds, the next faster 25 percent, the third such group, and the fastest 25 percent of the drivers. Each of the curves shows the spot-speed distribution for one of these groups. The graph as a whole is symmetrical about the average speed of 44.6 mph., but the individual distributions are slightly skewed away from the overall average speed.

Over a large part of the speed range there are substantial contributions from both the fast and the slow drivers. Even at as slow a speed as the 20-percentile (which is 38.6 mph. at the tangent location for which the graph was drawn), the slowest quarter of the drivers contribute only 42 percent of the observations, while 7 percent of them come from the fastest quarter of the drivers. These percentages were obtained by noting that the contributions of the four groups of drivers to the speed observations between 38.1 and 39.1 mph. constitute, respectively, 1.65 percent, 1.26 percent, 0.76 percent, and 0.29 percent of all the speed observations. In the same way we could find the respective contributions of the four groups of drivers in other parts of the speed range.

The graph can also be used to find out what percentage of all the speeds consists of speeds in any specified range contributed by one of the four groups of drivers. Suppose it is desired to find out what percentage of all the speeds consists of speeds between 35 and 40 mph. driven by drivers whose average speeds place them in the second quartile. The answer is given by the area under the "second quartile" curve between 35 mph. and 40 mph. The ordinate at 35 mph. is 0.65 and that at 40 mph. is 1.49, and the curve is nearly a straight line between these two points; therefore the area is approximately equal to the width of the interval times the average height, i.e., 5 mph. times 1.07 percent per mph., which is 5.35 percent. The entire area under each of the quartile curves is 25 percent of all the speeds.

The value of this graph lies not so much in its practical applications as in the insight it provides into the nature of the spot-speed distribution. What seems to the casual observer to be a simple more-or-less-normal distribution has been shown to be something far-more complex. To get a good grip on this "distribution of distributions" we have to examine it from many different points of view.

The last point of view which will be presented is that of Figure 19, which gives the spot-speed distributions when the drivers are grouped into 5-mph. ranges of average speed. This graph lacks the symmetry of the preceding one, since the overall average speed of 44.6 mph. is not symmetrically located with respect to the grouping of the drivers. One fact of interest which can be obtained from this graph is that one has to go up to 59 mph. to find a speed at which the drivers averaging 50 mph. or more provide more of the observations than the drivers averaging less than 50 mph. This illustrates once again how wrong it is to suppose—on this road, at least—that the speed problem involves only a small proportion of the drivers.

Speed Changes

It has already been pointed out that the average speed was about 6 mph. faster at the tangent than at the curve. But nothing was

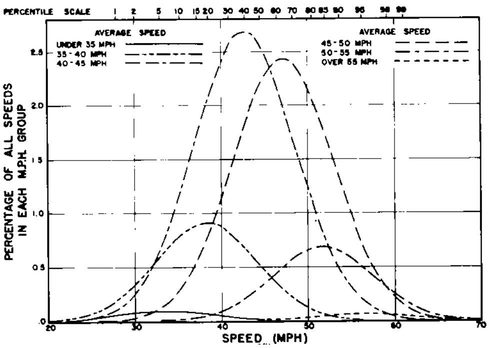

Figure 19. Distribution of individual speed observations for several groups of drivers at the tangent location.

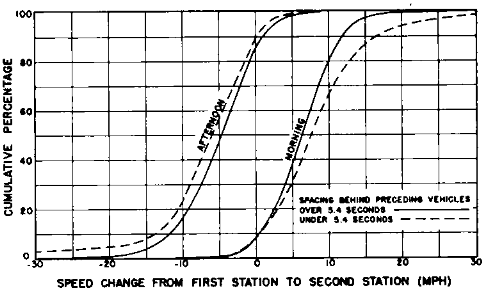

Figure 20. Distribution of individual speed changes.

said about the individual speed changes as the driver proceeded from the one location to the other. Since these speed changes are influenced by the presence of other cars, the following material uses only those cases where the clear space ahead of the vehicle was known.

The solid curves of Figure 20 show the distribution of speed changes between the tangent and the curve for those observations where the car was preceded by a clear gap of 0.0015 hour (5.4 seconds) or more at both stations. Even though this is a very strict criterion for insuring that a car is uninfluenced by other traffic, it was met in 76 percent of the observations for which the time spacings were obtained. When these cars were going from the tangent to the curve in the afternoon, the median speed reduction was 4.8 mph. In the morning, when the direction of travel was from the curve to the tangent, the median increase was 6.5 mph.

The dashed curves present the same information for the cars which did not have as long a clear space in front of them. For these cars, the median reduction from the tangent to the curve was 6.2 mph., while the median increase when they were going the other way was 7.7 mph.

Only tentative suggestions can be offered as to why the speed changes were larger in the morning than in the afternoon. Perhaps the drivers proceeding from the tangent to the curve are reluctant to slow down until the last minute, while those going the other way, after having driven slowly through the series of curves, are eager to "step on it" when the road finally straightens out. Or it may be that the inbound drivers are unable to accelerate before reaching the curve because of the upgrade which flattens out between the two stations.

Relation Between Speed and Time

Since commuters often have to be in the city at a fixed time, it was thought that the drivers going toward the city might have some tendency to travel faster than usual when they were behind schedule. No such tendency was found. At each of the two morning stations, the correlation between deviations from a driver's average time (the amount by which he was earlier or later than usual) and the corresponding deviations from his average speed (the amount by which he traveled faster or slower than usual) was too small to be statistically significant. Even when a driver was as much as 10 minutes late, which happened about 10 percent of the time, there was no tendency to exceed his usual speed. Whatever the factors determining a driver's speed on a particular morning, it is apparently not much influenced by variations of a few minutes one way or the other.

CONCLUSIONS

Comparison Between Study Locations

Speeds were recorded at two locations (the tangent and the curve) and during two parts of the day (morning and afternoon), thereby providing four sets of data. At each location the average speed was about the same in both the morning and the afternoon. Though the speeds averaged 6 mph. faster at the tangent than at the curve, the spread was about the same at both locations.

In the morning, the speed increase from the curve to the tangent location had a median value of 6.5 mph., while the median decrease in the afternoon was 5.2 mph. The changes in speed were less than these amounts for the free-moving cars; they were greater for cars which were influenced by other cars in front of them.

Relation of Average Speed to Driver and Car Characteristics

The principal characteristics which were found to be related to the average speeds of different drivers are the driver's age, his annual mileage, and the age of the car. Higher speeds are associated with younger drivers, larger amounts of travel, and newer cars. But no combination of these factors could explain more than a small fraction of the total variation in average speed.

Variability Within and Between Different Drivers

The variation in speeds of the same driver on different days was greater, on the average, than the variation among the average speeds of different drivers. The standard deviations of the two distributions were 5.67 and 4.33 mph., respectively. Both figures apply to all four stations.

Based on these figures, a theoretical model was developed which provides further insight into the nature of the spot-speed distribution. As an example of the deductions which were made from the model, it was proved that about a third of all drivers have an 85-percentile speed which exceed the 85-percentile value in the spot speed distribution. To take another example, if a set of drivers are all observed as many as seven times, more than half of them can be expected to exceed the 85-percentile speed (based on all their speed observations) at least once.

Curves were developed showing the percentage of speeds above specified values which are driven by various percentages of the fastest drivers. For example, the fastest 10 percent of the drivers provide a third of all the speeds faster than the 85-percentile. Similar figures are available for groups of the slowest drivers.

The "average" driver, i.e., the driver whose average speed is equal to the overall average, can be expected to exceed the 85-percentile speed about 11 percent of the time. The fastest 15 percent of the drivers contribute 46 percent of the speeds over the 85-percentile speed. But it is equally important to remember that the remaining 54 percent of these speeds are contributed by drivers who are not among the fastest 15 percent.